

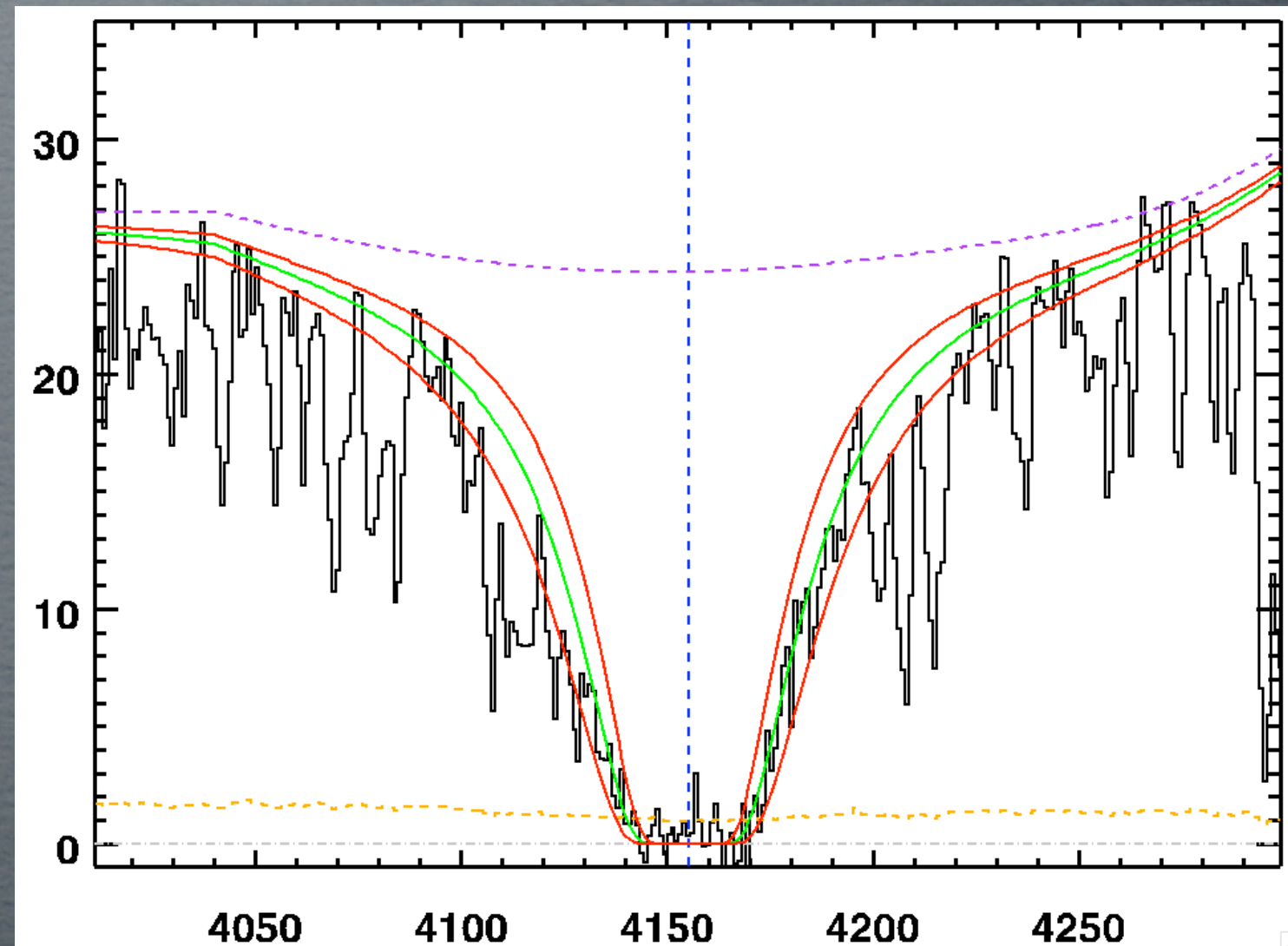
THE SDSS-DR3 DAMPED LY α SURVEY

JASON X. PROCHASKA
UCO/LICK OBSERVATORY



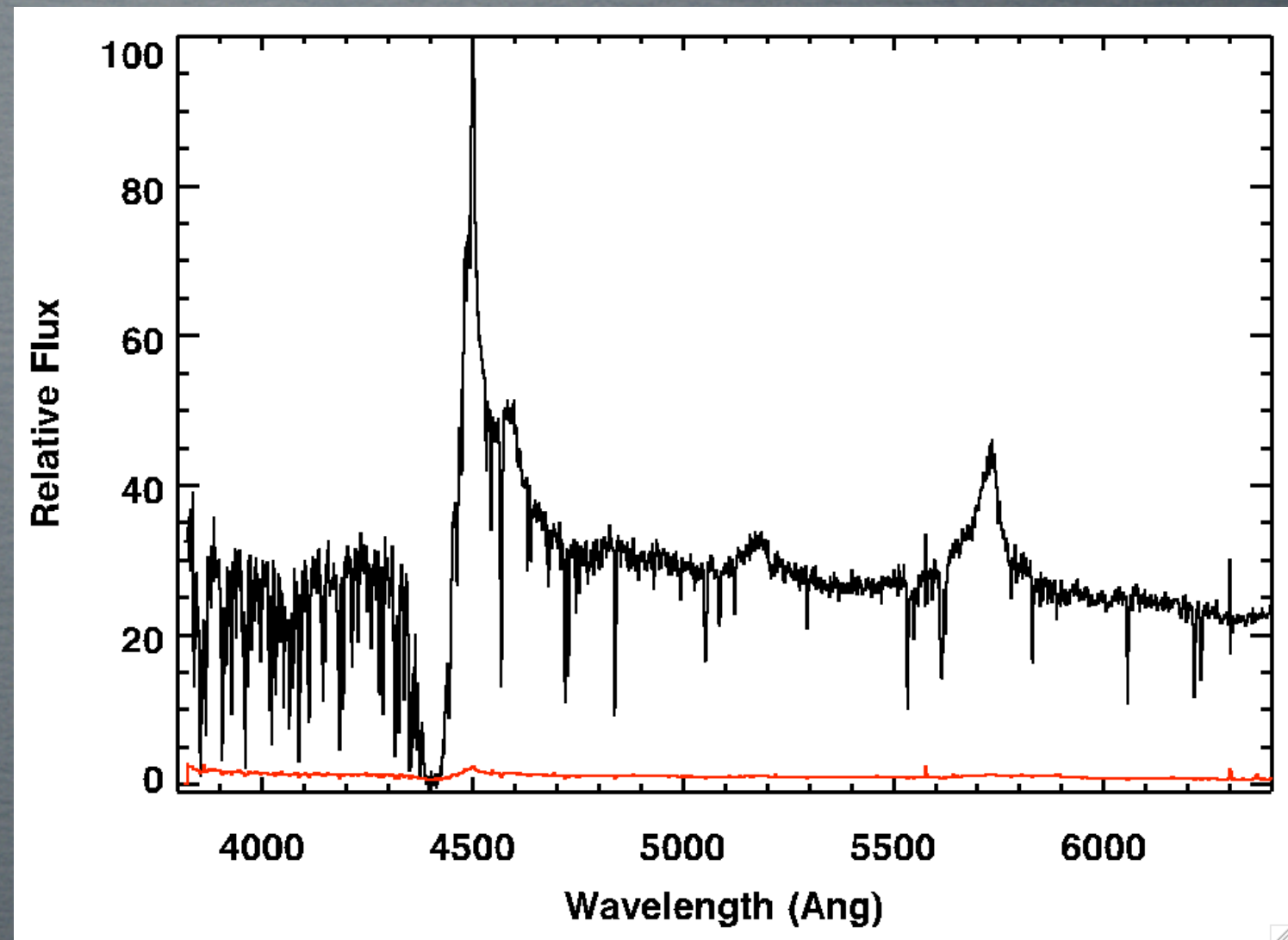
DAMPED LY α SYSTEM DEFINED

- $N(\text{HI}) > 2 \times 10^{20} \text{ cm}^{-2}$
 - ✦ DOMINANT RESERVOIR OF NEUTRAL GAS
 - ✦ LARGE $N(\text{HI}) \Rightarrow \delta\rho/\rho \gg 100$
 - ✦ PROGENITORS OF MODERN DAY GALAXIES
- IDENTIFIED IN ABSORPTION
 - ✦ OPTICAL DEPTH WEIGHTED $\tau \sim n\sigma$
 - ✦ NOT RESTRICTED TO THE BRIGHT END
 - ✦ \Rightarrow GREATER DIVERSITY OF MASS, LUMINOSITY,



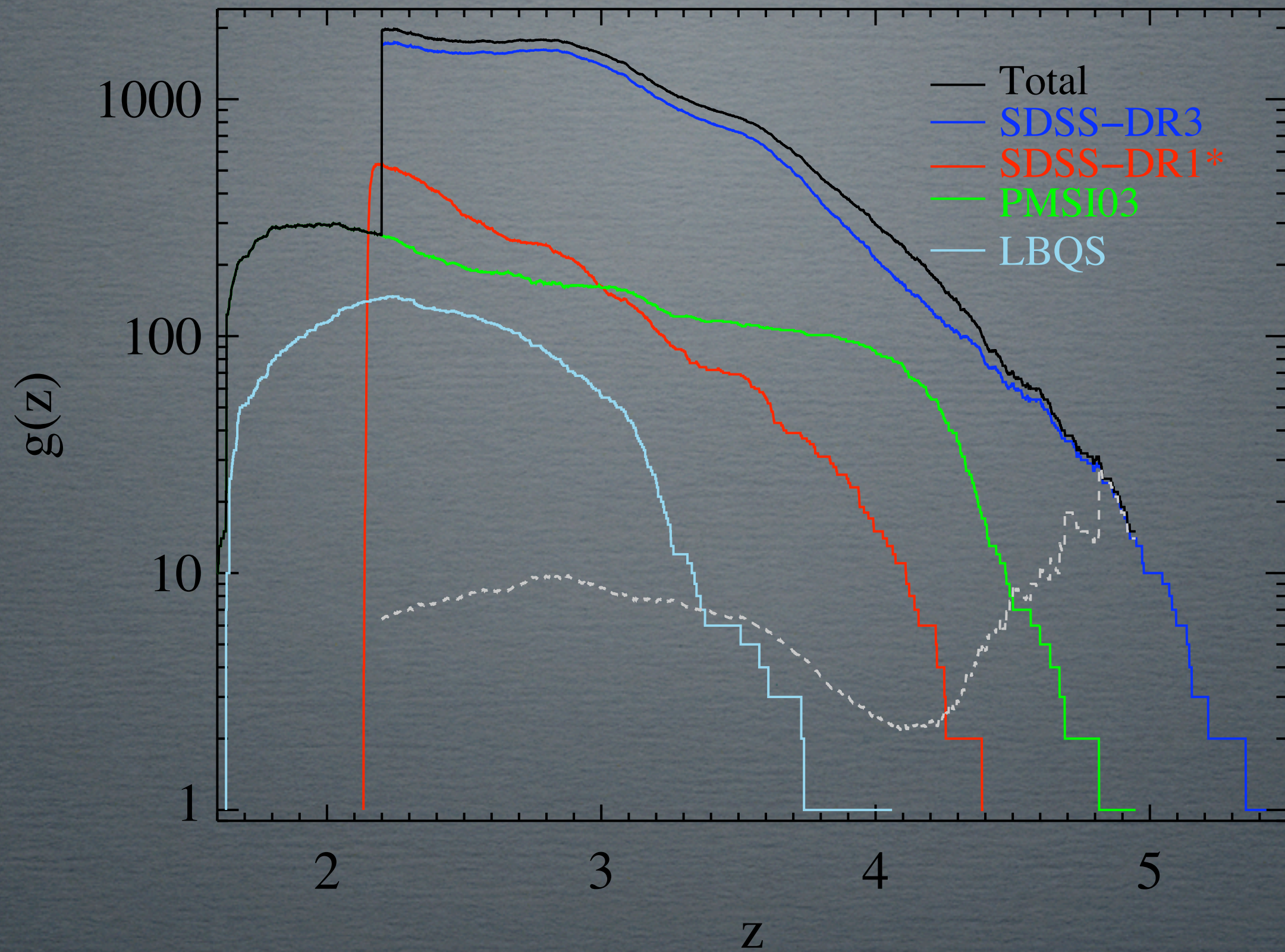
SDSS DATABASE

- QUASAR SAMPLE
 - ✦ DR3: OVER 40000
 - ✦ $z > 2$: 8000 QUASARS
- AUTO DLA SEARCH
 - ✦ SIMPLE ALGORITHM
 - ✦ 2000 CANDIDATES
- HUMAN ANALYSIS
 - ✦ VISUAL VERIFICATION
 - ✦ CAREFUL $\text{Ly}\alpha$ ANALYSIS

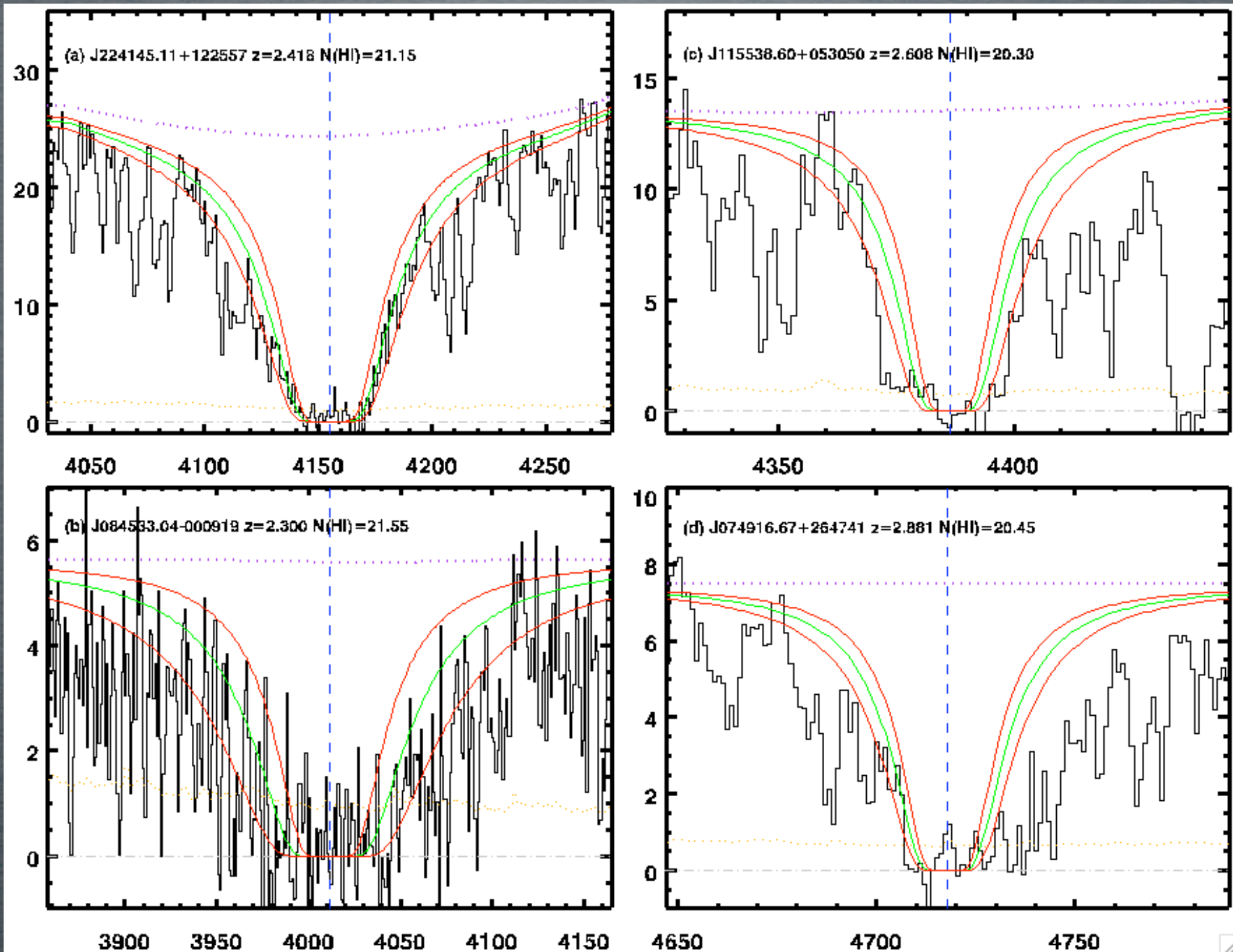


PROCHASKA & HERBERT-FORT (2004)

SENSITIVITY FUNCTION

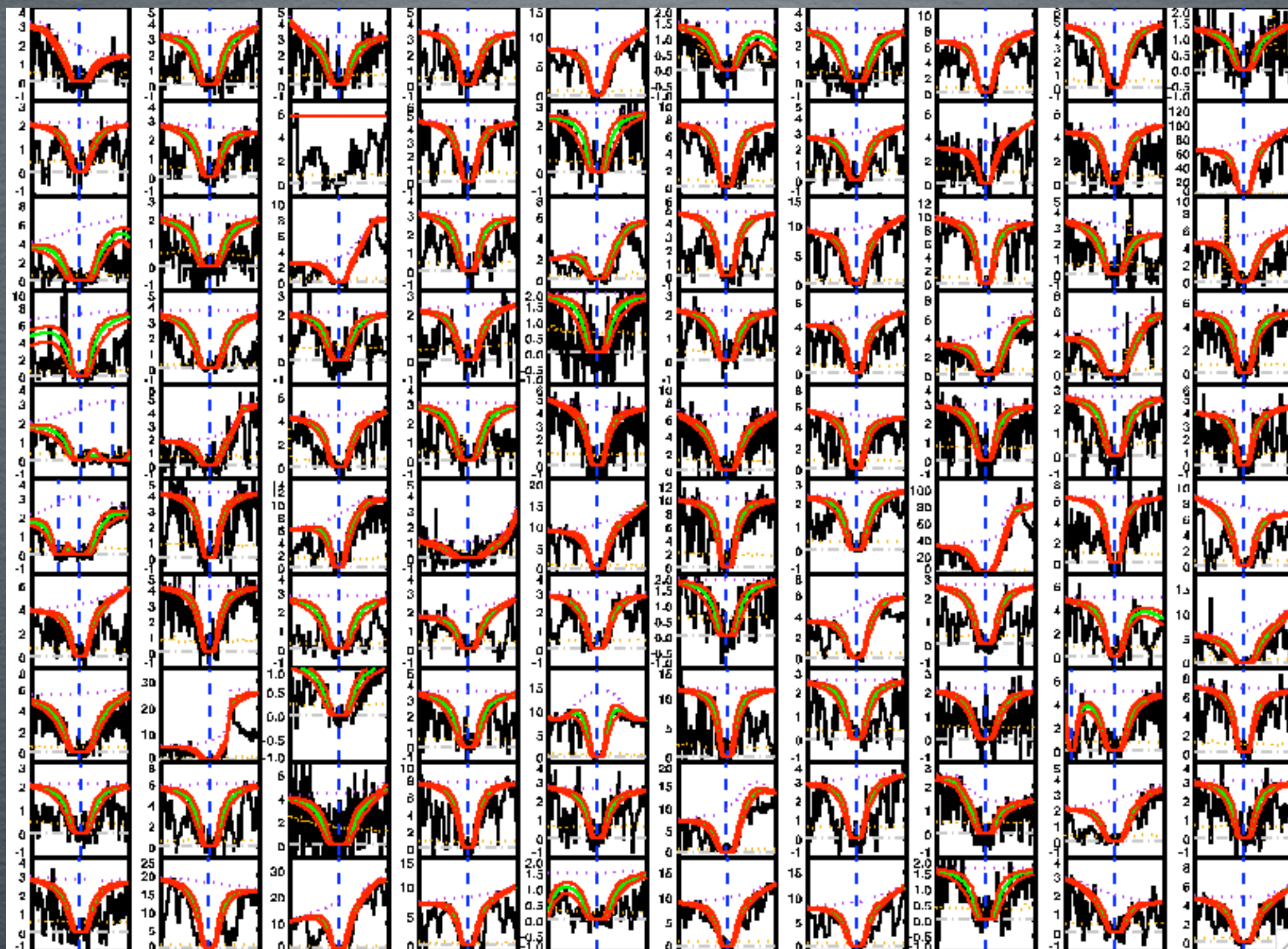


EXAMPLE LY α FITS



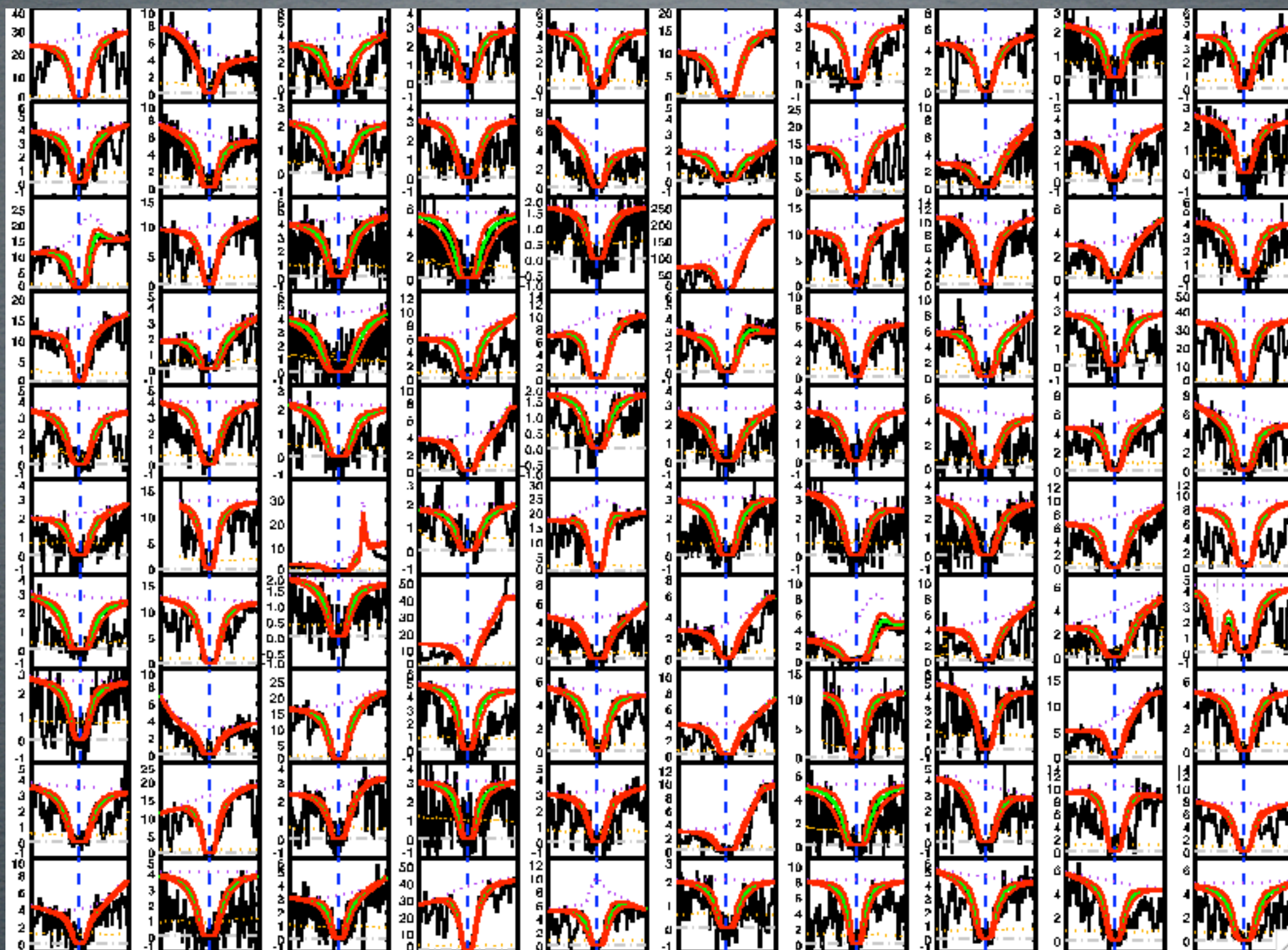
THE FITS...

1-100



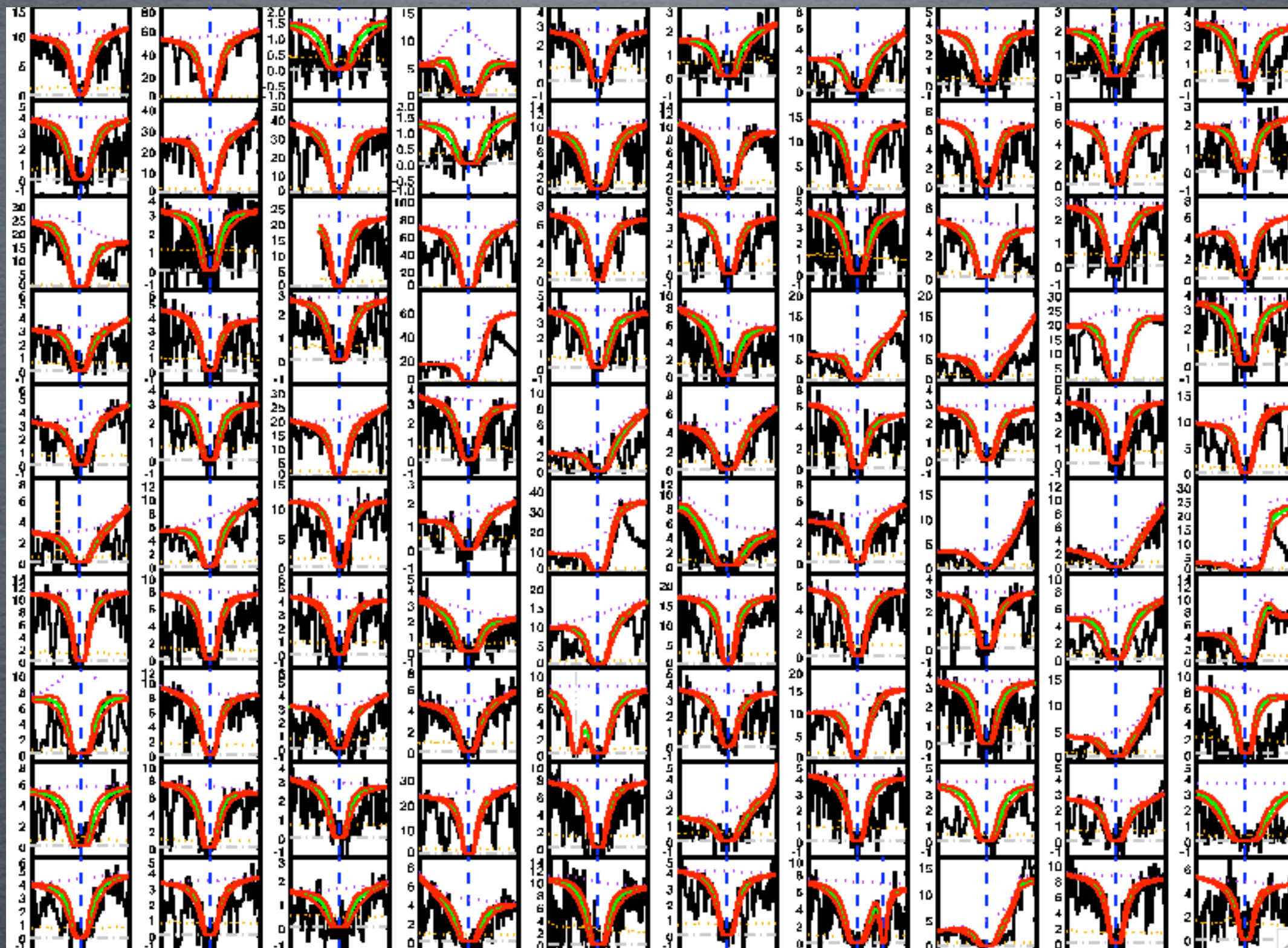
THE FITS...

101-200



THE FITS...

201-300



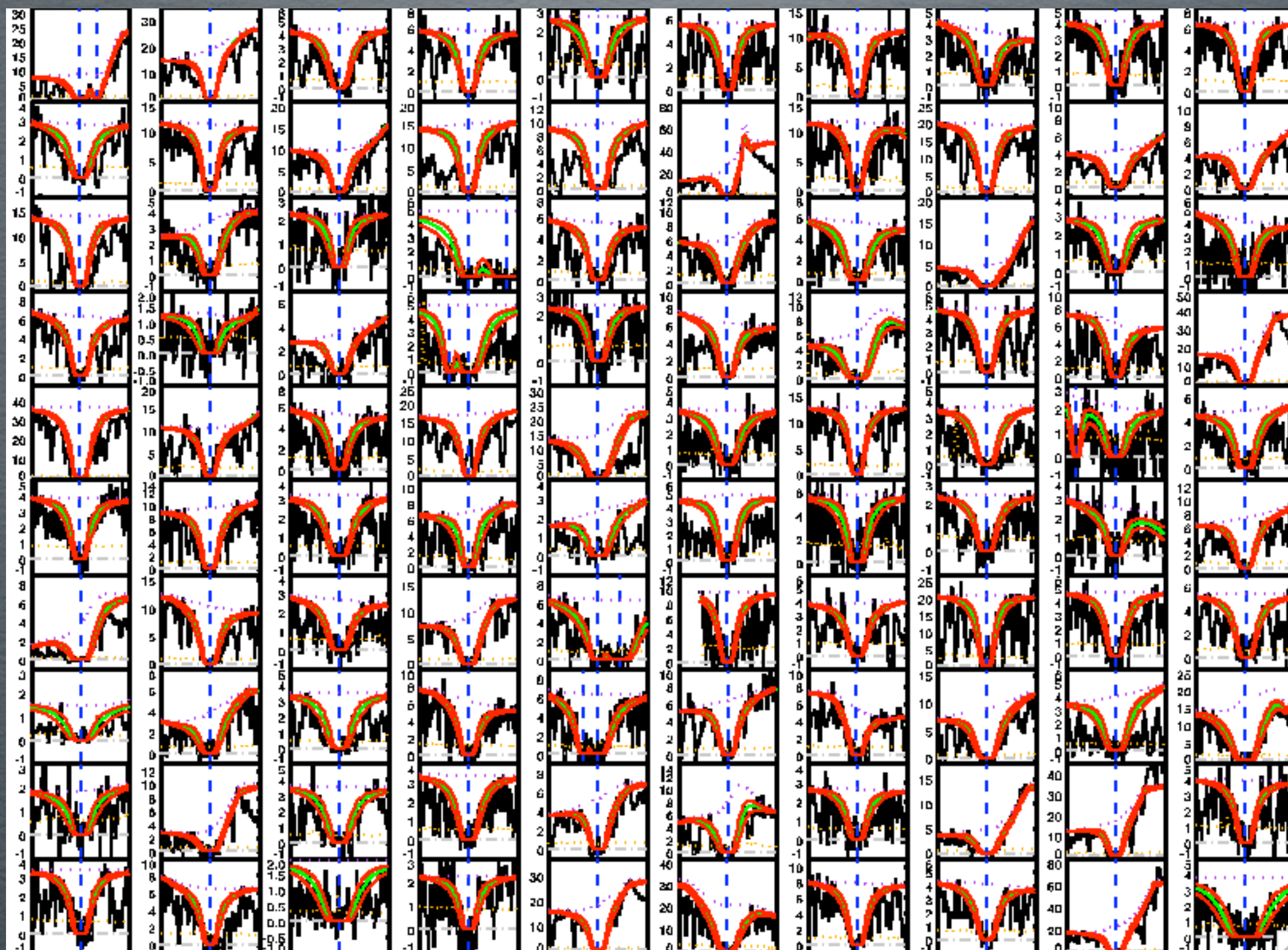
THE FITS...

301-400



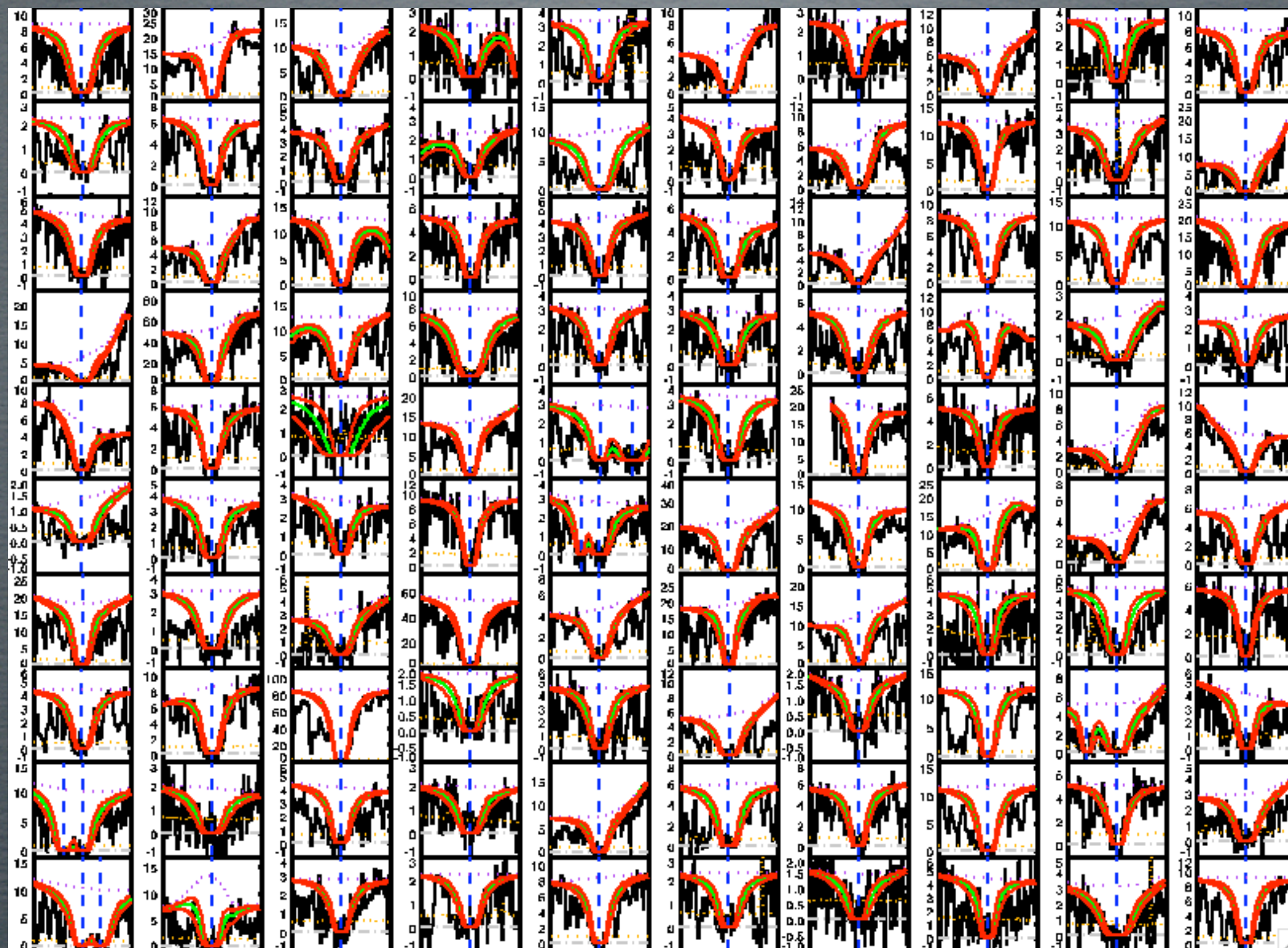
THE FITS...

401-500



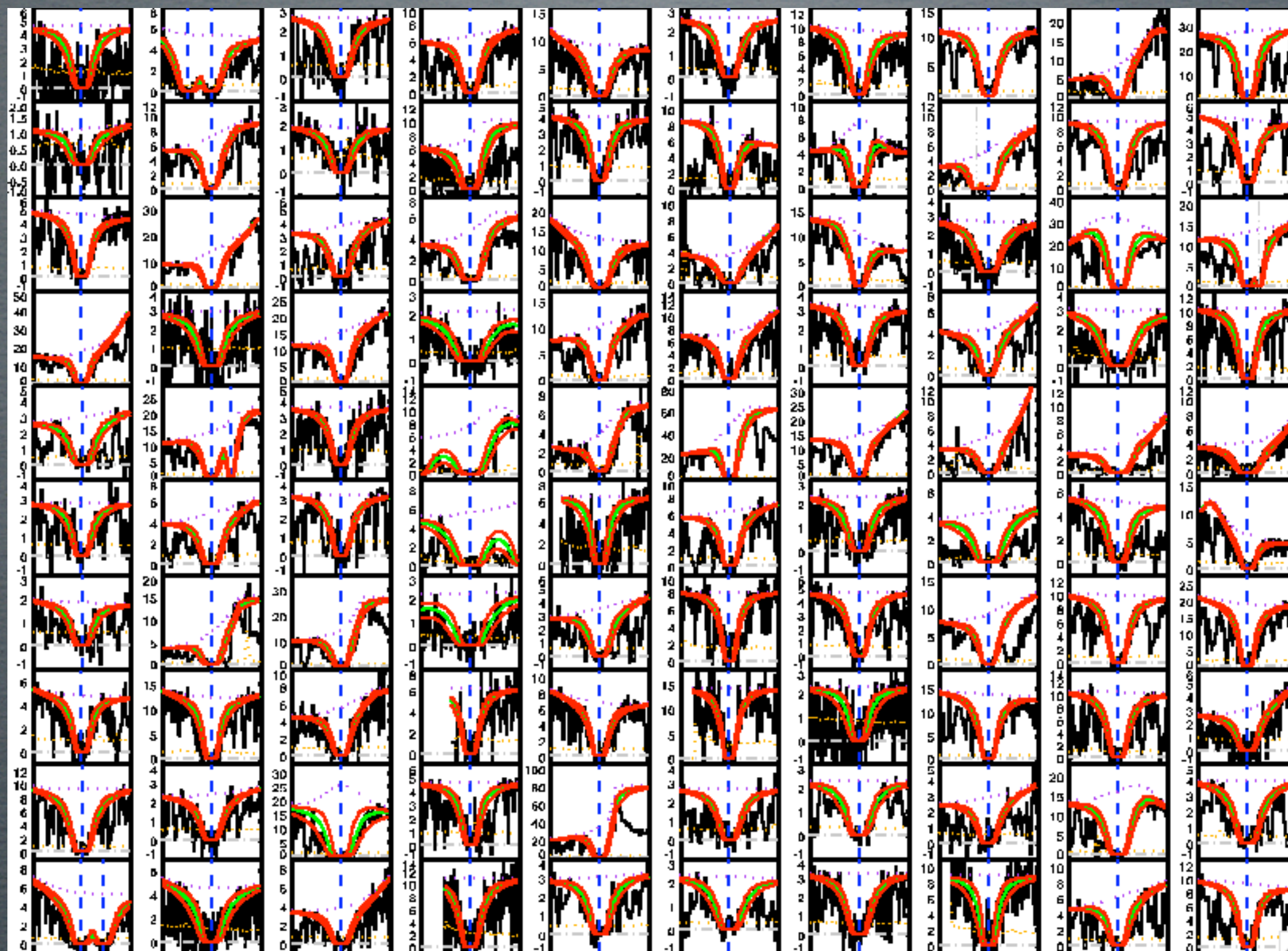
THE FITS...

501-600



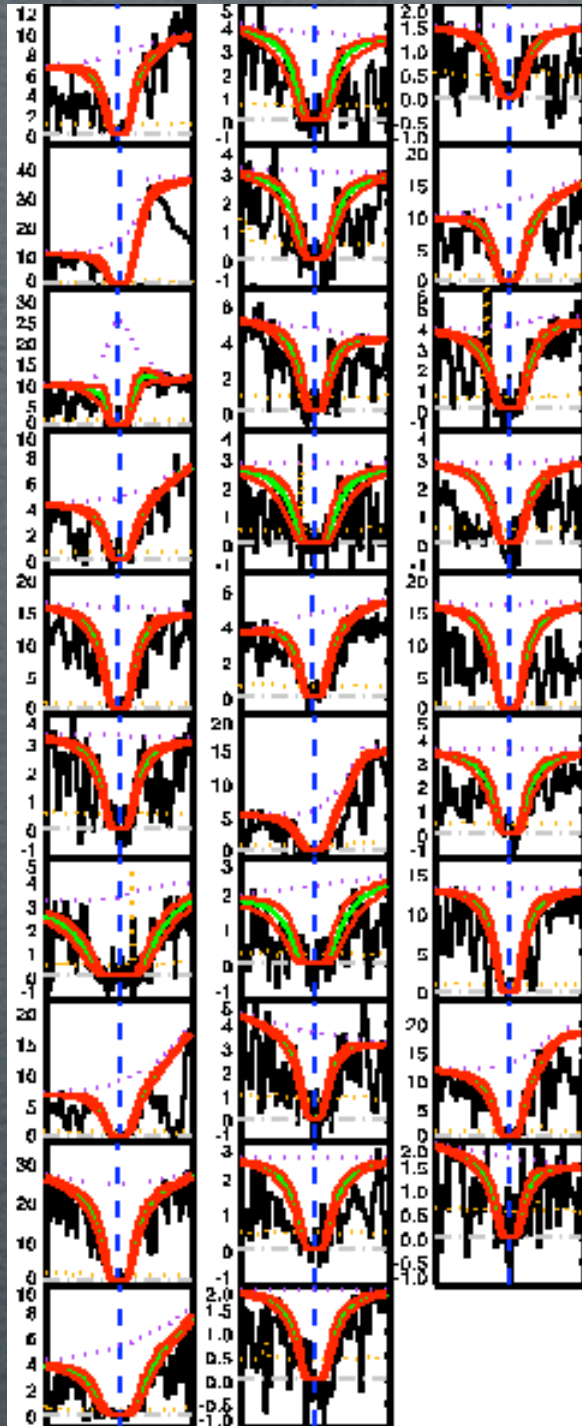
THE FITS...

601-700

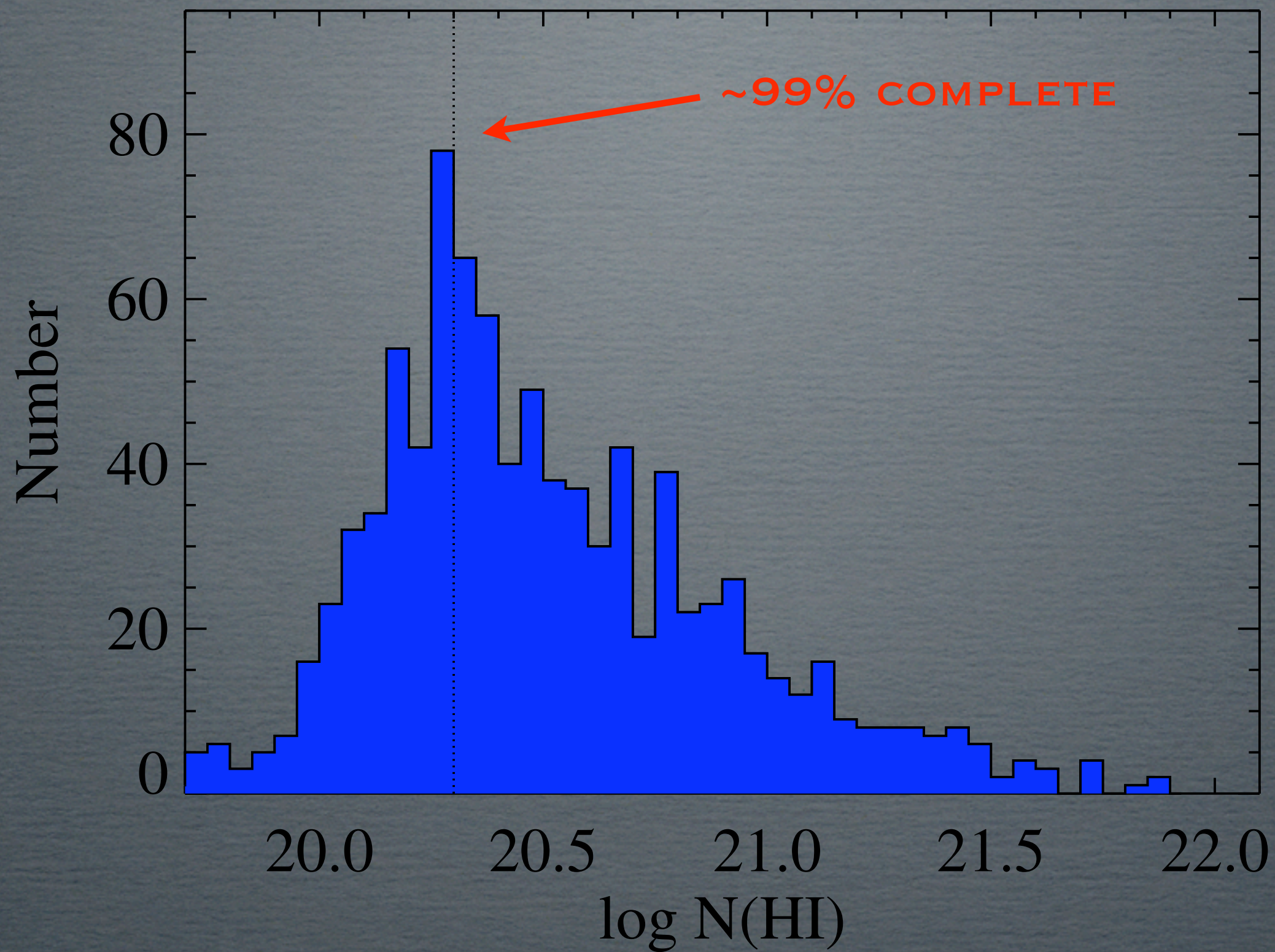


THE FITS...

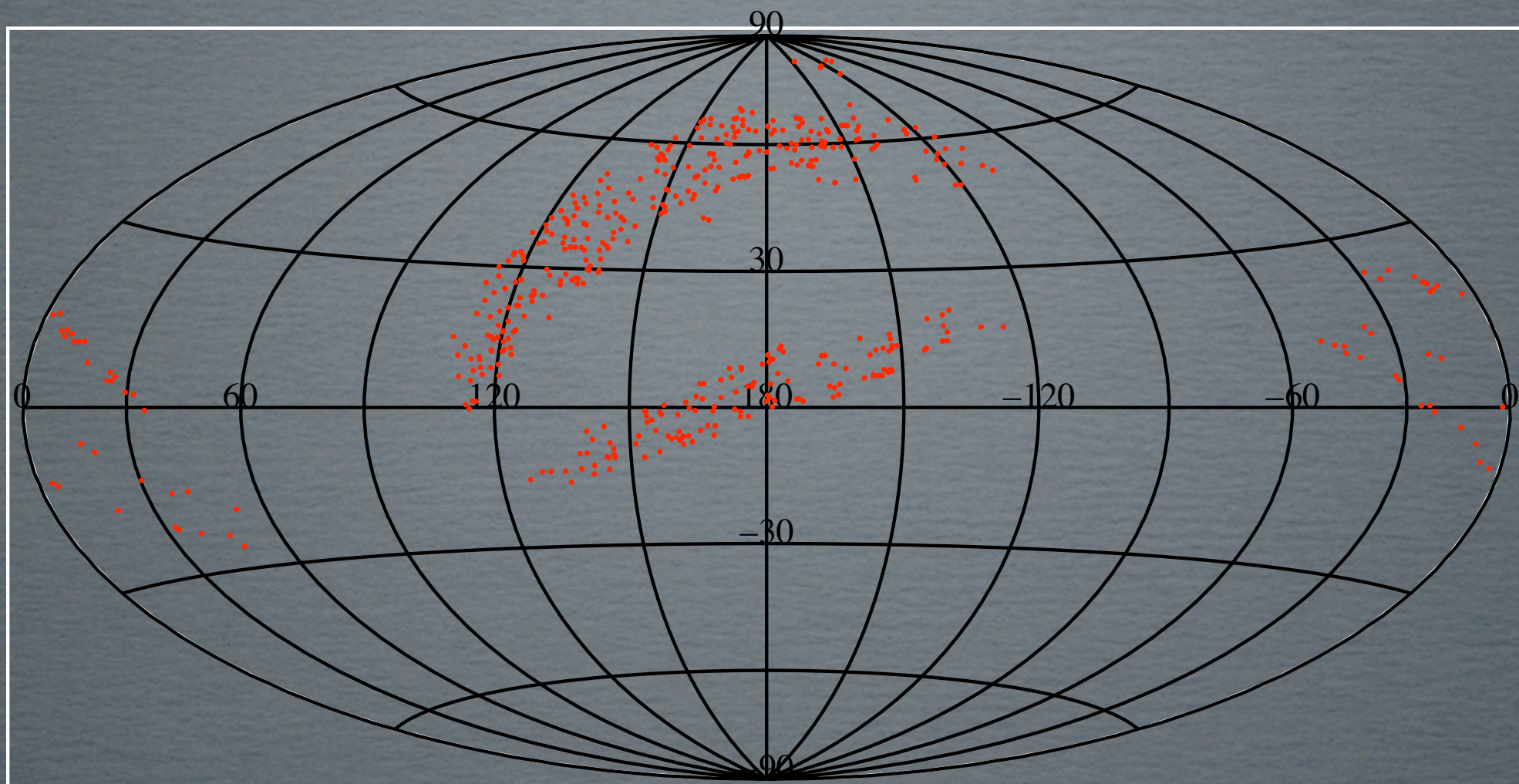
701-739



N_{HI} HISTOGRAM



SKY PLOT



- MINIMUM SEPARATION

- ◆ 3 ARCMINUTES

- ◆ $\Delta z = 0.1$

- MINIMUM SEPARATION WITH $\delta v < 1000$ KM/S

- ◆ 20 ARCMINUTES

- ◆ CLUSTERING ANALYSIS?

f_{HI} : N_{HI} FREQUENCY DISTRIBUTION

- $f_{\text{HI}}(N)$

- ◆ 525 SDSS DLA

- ◆ SINGLE IS POOR

- ◆ BREAK $N_{\text{HI}} \sim 21.5$

- ▶ Ω_g CONVERGES!!

- ▶ ARE YOU CONVINCED?

- ◆ 'FAINT' END: $\alpha \sim -2$

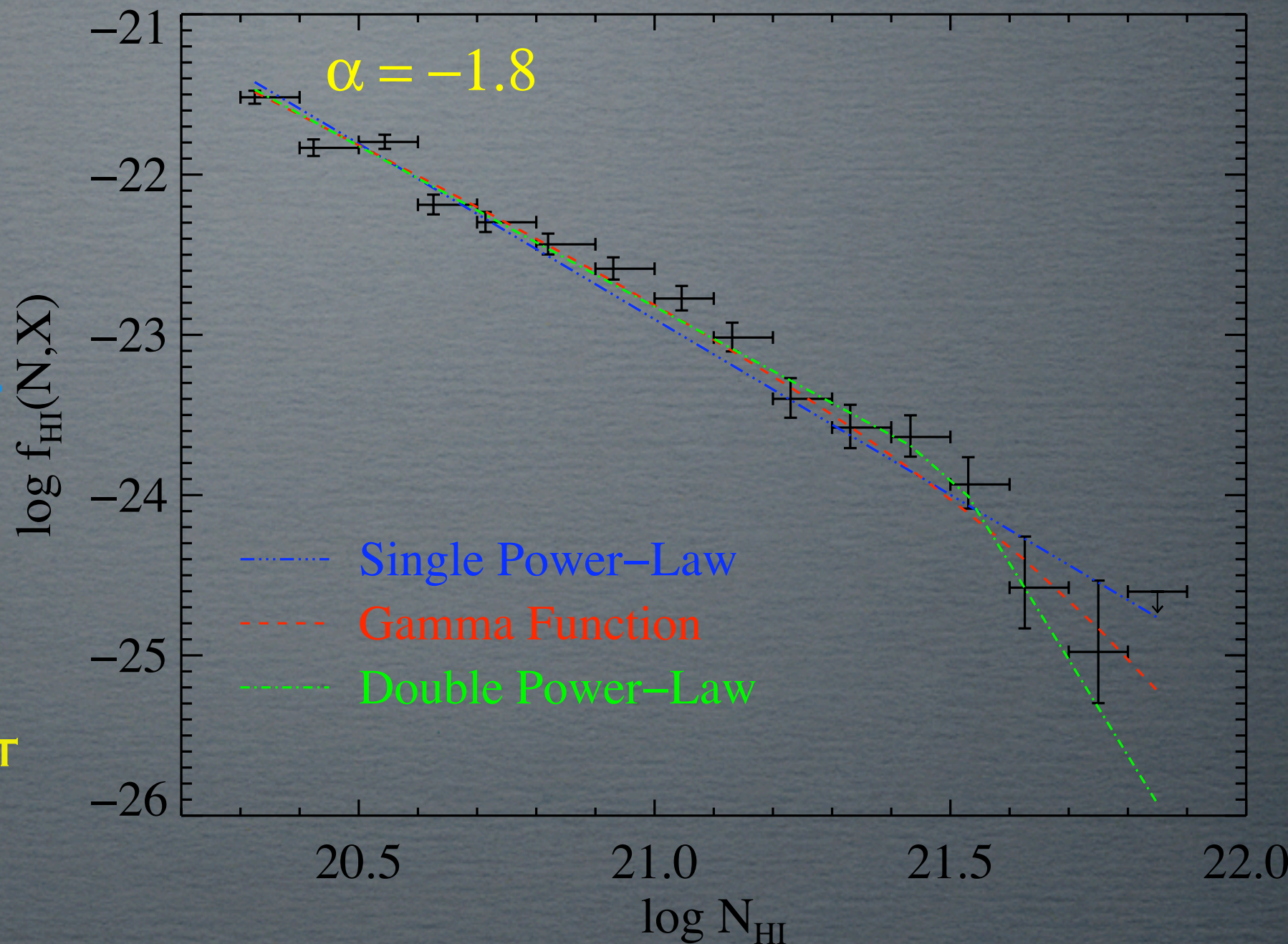
- ◆ BRIGHT END

- ▶ STEEPER THAN -3

- Z EVOLUTION

- ◆ SHAPE IS INVARIANT

- ◆ NORMALIZATION
INCREASES WITH Z



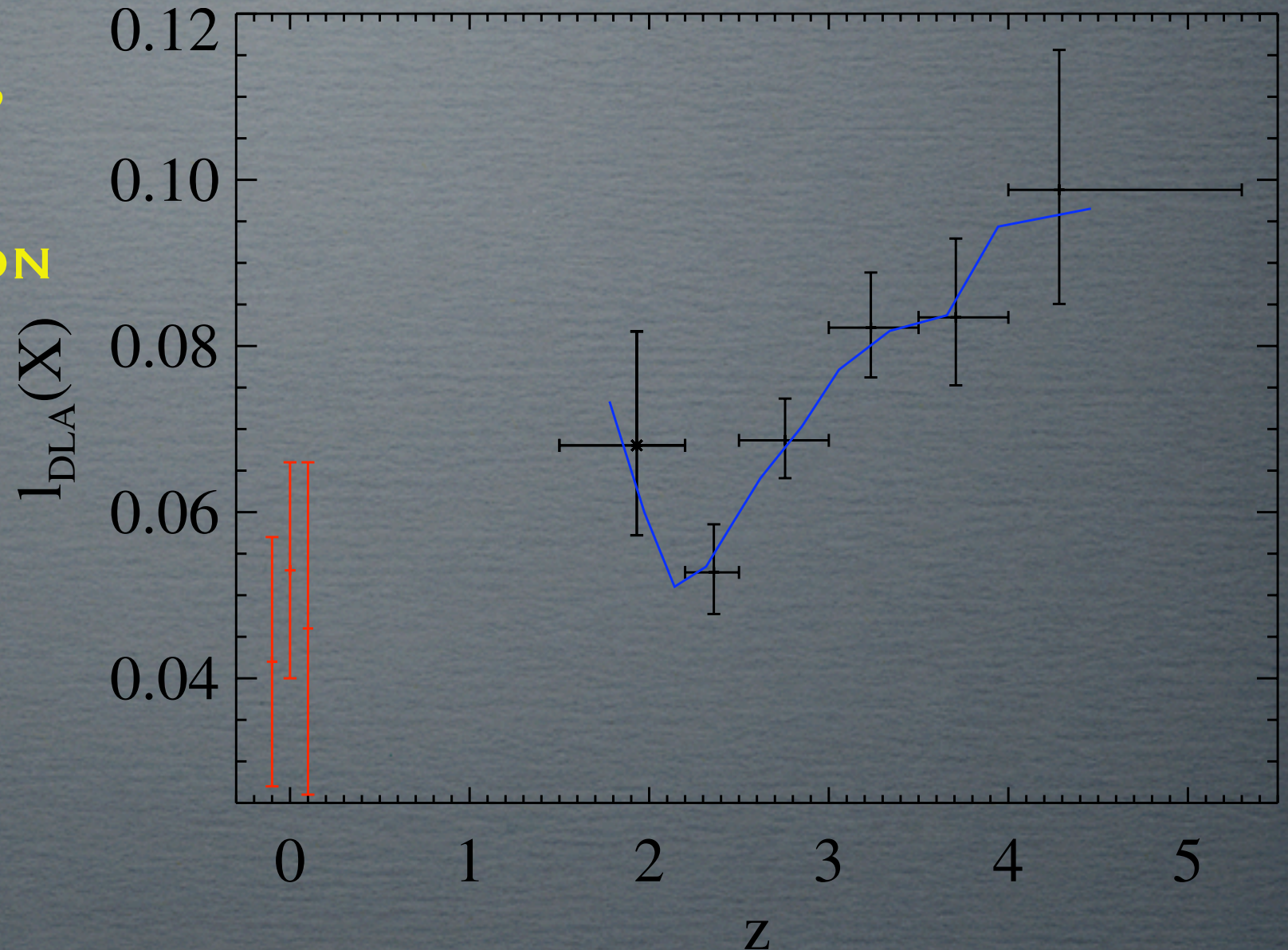
LINE DENSITY: $\ell_{\text{DLA}}(X)$

• $\ell(X)$

- ◆ INCIDENCE OF DLA PER 'ABSORPTION DISTANCE'
- ◆ OFTEN WRITTEN dn/dX
- ◆ DLA COVERING FRACTION
 $\ell \sim n A$

• RESULTS

- ◆ $\ell(X)$ DECREASES BY 2X FROM $z=3.3$ TO 2.3
- ◆ MINIMAL EVOLUTION AT ENDPOINTS
- ◆ IS $\ell(X)$ FLAT FROM $z=2$ TO TODAY?!



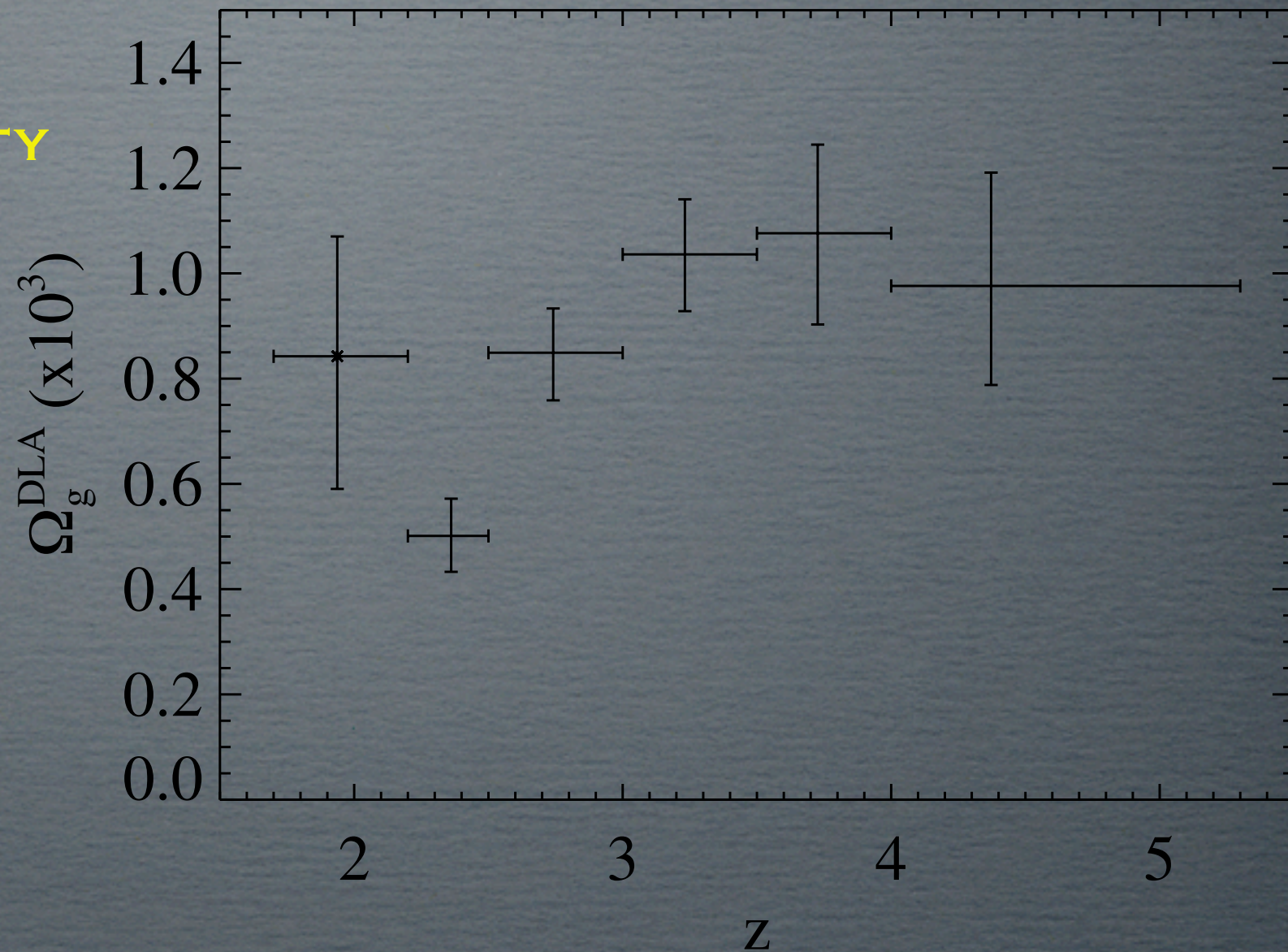
NEUTRAL GAS MASS DENSITY: Ω_g

- Ω_g

- ◆ NEUTRAL GAS DENSITY
- ◆ COSMOLOGICAL QUANTITY
- ◆ RESERVOIR FOR SF

- RESULTS

- ◆ FIRST EVIDENCE FOR SIGNIFICANT EVOLUTION
- ◆ ALSO, A FACTOR OF ~ 2 DECREASE FROM $z = 3.3$ TO 2.3



THEORISTS: TIME TO WAKE UP!!



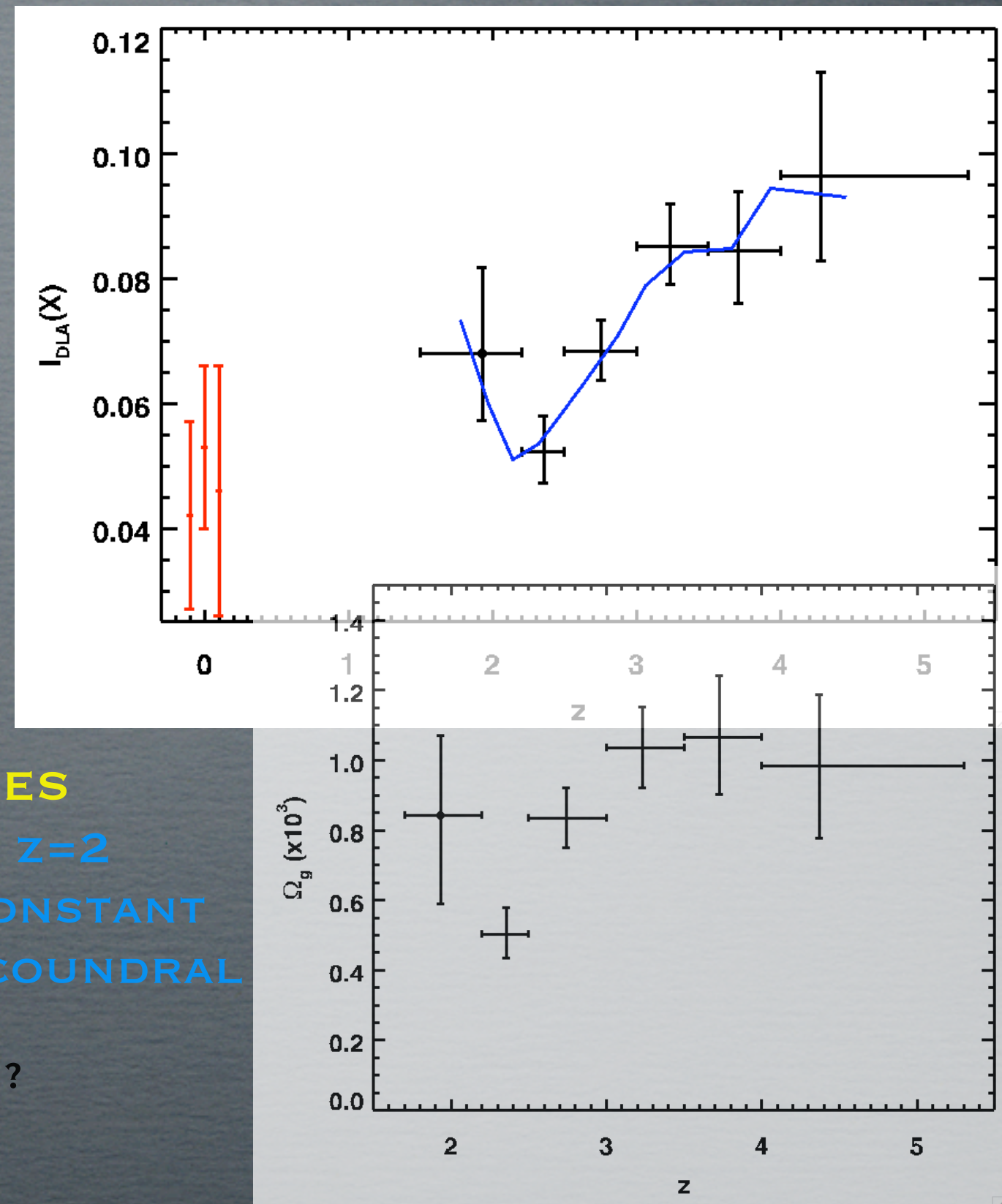
IMPLICATIONS OF THE EVOLUTION

• LINE DENSITY

- ✦ EITHER n OR A (OR BOTH) DROPS BY 2 IN <1 GYR
- ✦ CONSIDER n
 - ▶ P-S: $M^* \sim 10^{10} M_{\text{SUN}}$ ($z=3$)
 - ▶ $M \gg M^*$ HAVE n INCREASING
 - ▶ $M \ll M^*$ HAVE n NEARLY CONST
- ✦ THEREFORE, A IS CHANGING

• Ω_g

- ✦ GAS DENSITY DROPS BY 2
- ✦ CONSIDER PHYSICAL PROCESSES
 - ▶ SF: UNLIKELY, SF PEAKS BELOW $z=2$
 - ▶ IONIZATION: UNLIKELY, EUVB CONSTANT
 - ▶ FEEDBACK: LAST RESORT OF A SCOUNDRALE
 - ➔ AGN, SF, GALACTIC WINDS?
 - ➔ WHY WOULD SFR PEAK BELOW $z=2.3$?



COMPARISON WITH CDM: I

- $f_{\text{HI}}(N)$: $z=3$

- ♦ **SAMS:**

- ▶ CORRECT SHAPE
 - ▶ LOW NORMALIZATION

- ♦ **SPH**

- ▶ GOOD AT HIGH N_{HI}
 - ▶ VERY LOW AT LOW N_{HI}
 - ▶ UNDER PREDICT $\ell(X)$

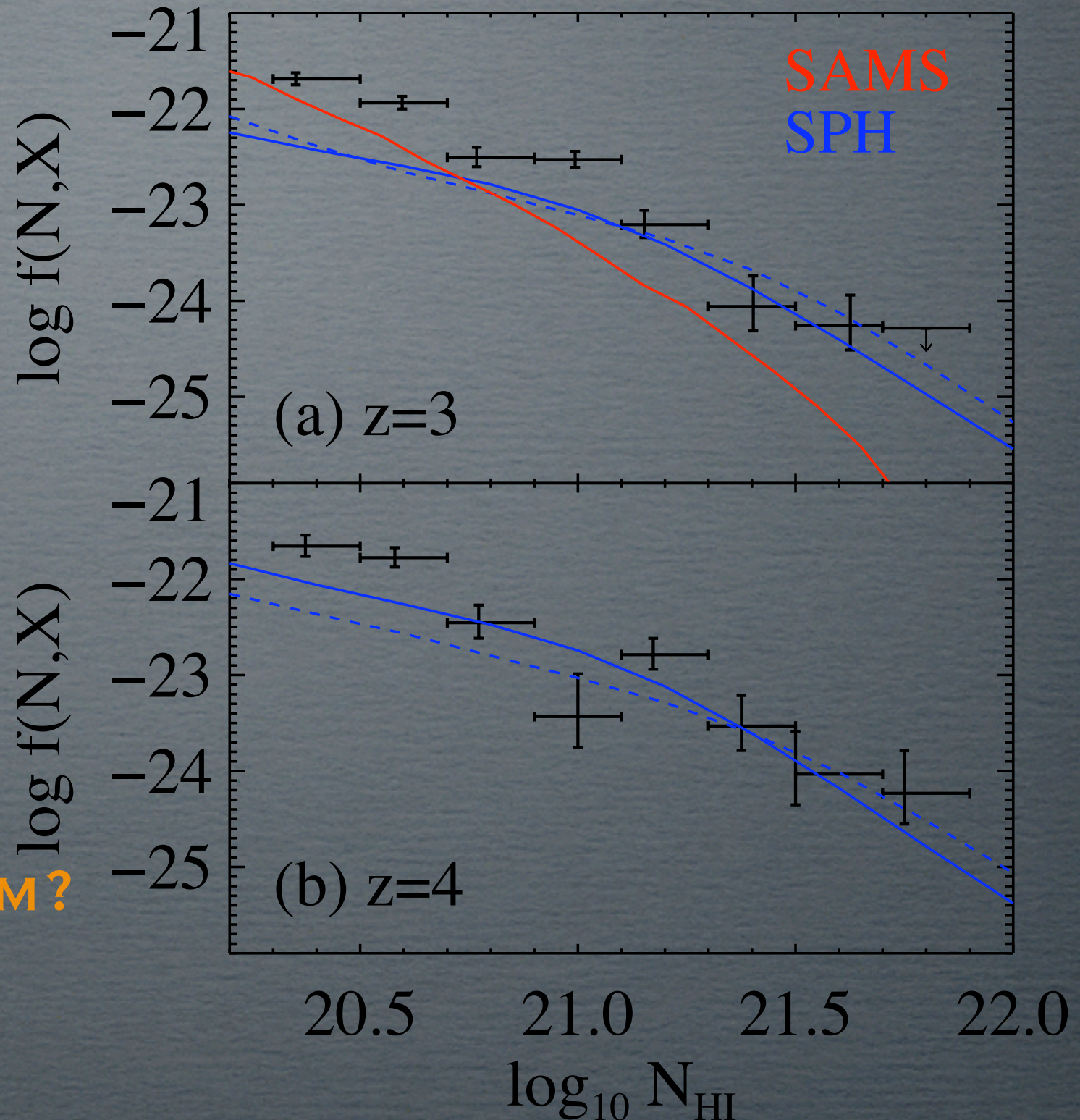
- $f_{\text{HI}}(N)$: $z=4$

- ♦ **SPH**

- ▶ AGAIN, LOW AT LOW N_{HI}
 - ▶ PARTLY OBSERVATIONAL?

- **FUNDAMENTAL PROBLEM?**

- ♦ $f_{\text{HI}}(N)$ VS KINEMATICS



COMPARISON WITH CDM: II

- Ω_g

- ♦ **SAMS:**

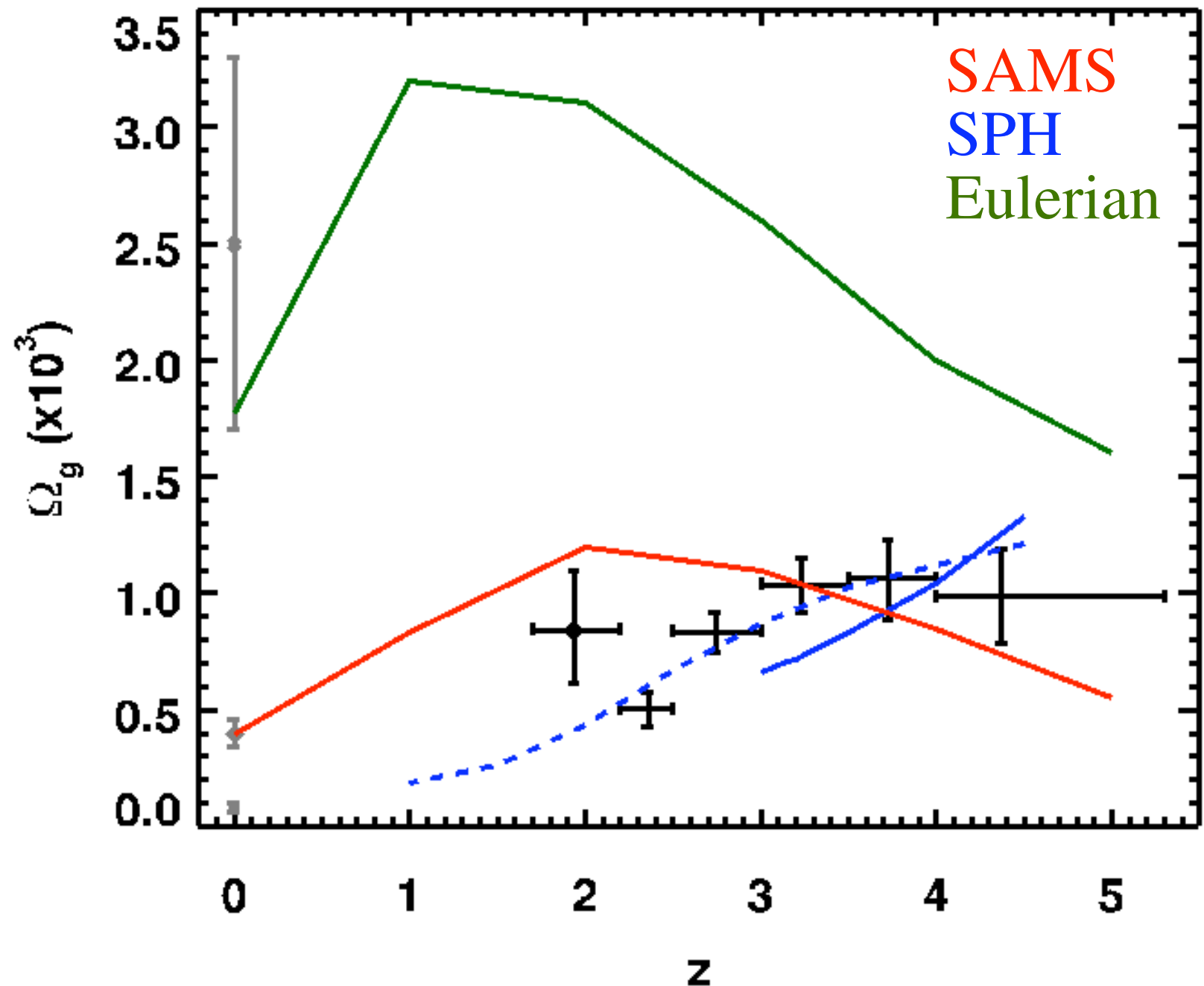
- ▶ FINE AT HIGH z
- ▶ TOO HIGH AT LOW z ?
- ▶ NOT ENOUGH FEEDBACK?

- ♦ **SPH**

- ▶ LOW RES IS EXCELLENT
- ▶ HIGH RES IS TOO LOW
- ▶ PROBLEM?

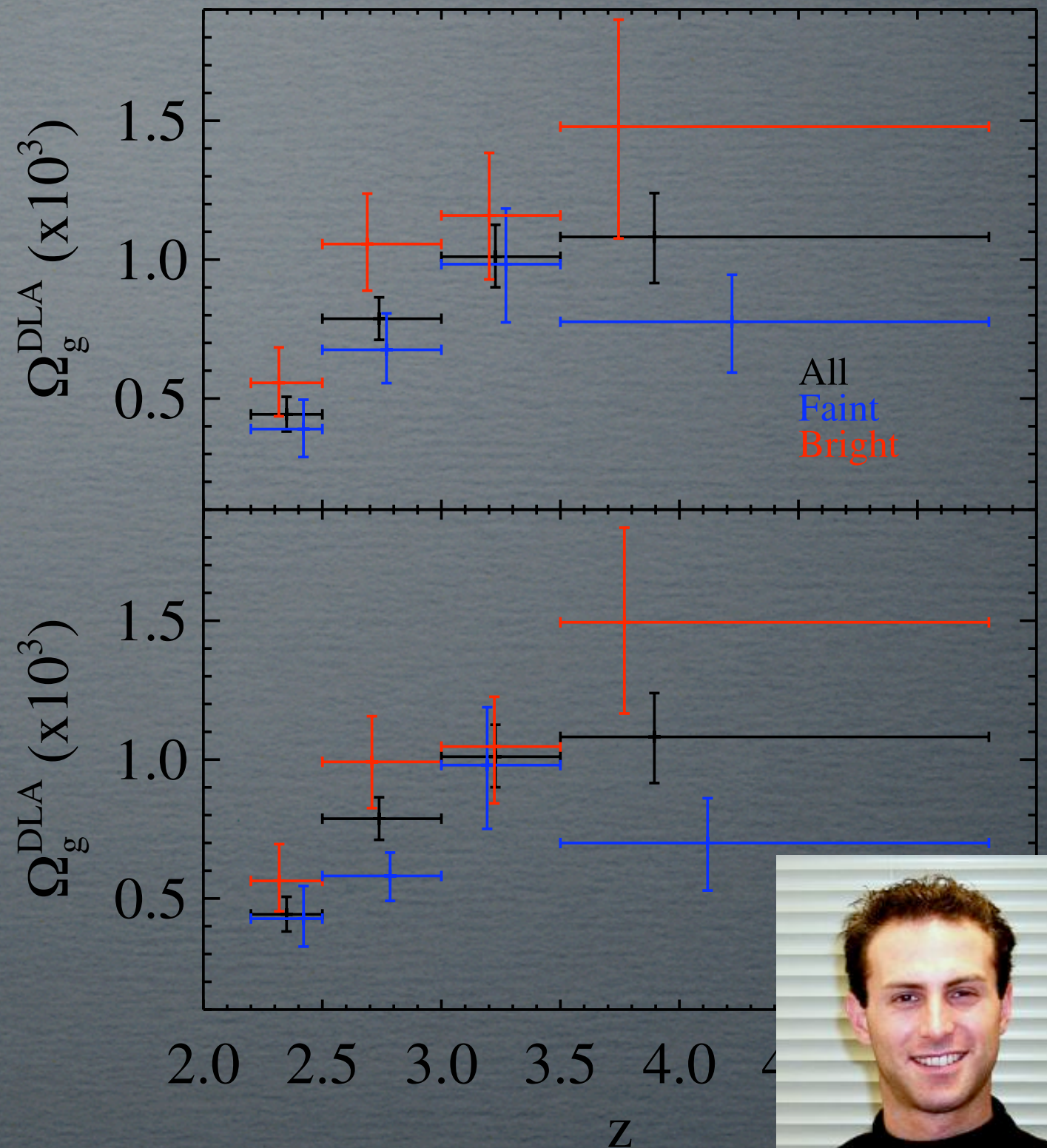
- ♦ **EULERIAN**

- ▶ TOO MUCH GAS!
- ▶ DUST OBSCURATION?



SYSTEMATIC ERROR: III

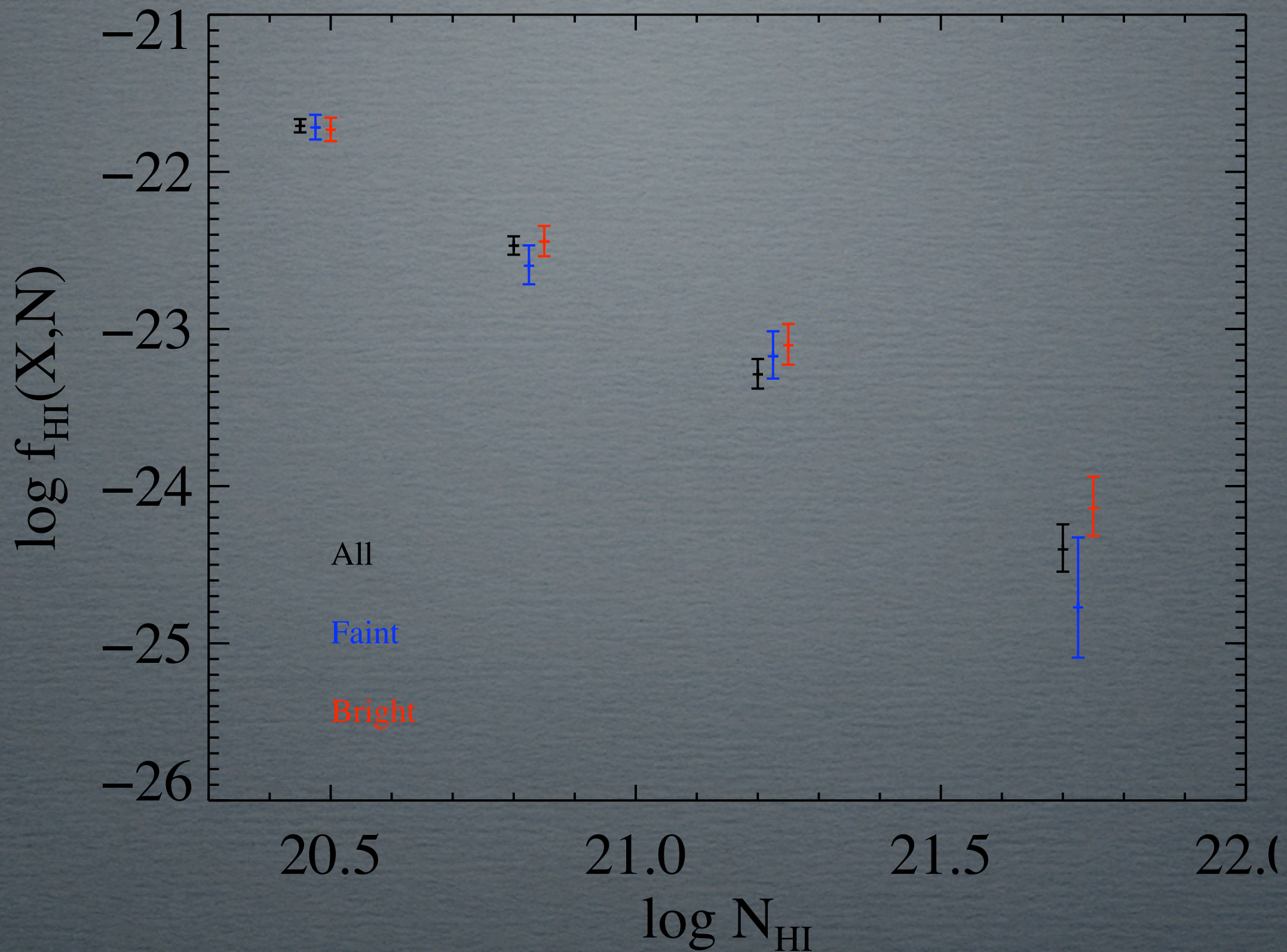
- Ω_g
 - ♦ HIGHER TOWARD BRIGHTER QUASARS!
 - ♦ SAME IS TRUE FOR SNR
- EXPLANATIONS:
 - ♦ SAMPLE VARIANCE? No
 - ♦ INTRINSIC? UNLIKELY
 - ♦ MISSED DLA? DOUBTFUL
 - ♦ OVERESTIMATE BRIGHT? No
 - ♦ UNDERESTIMATE FAINT? MAYBE
 - ♦ DUST OBSCURATION? NO!!
 - ♦ GRAVITATIONAL LENSING? QUITE POSSIBLE!!



MICHAEL MURPHY (IOA)



f_{HI} FOR BRIGHT/FAINT



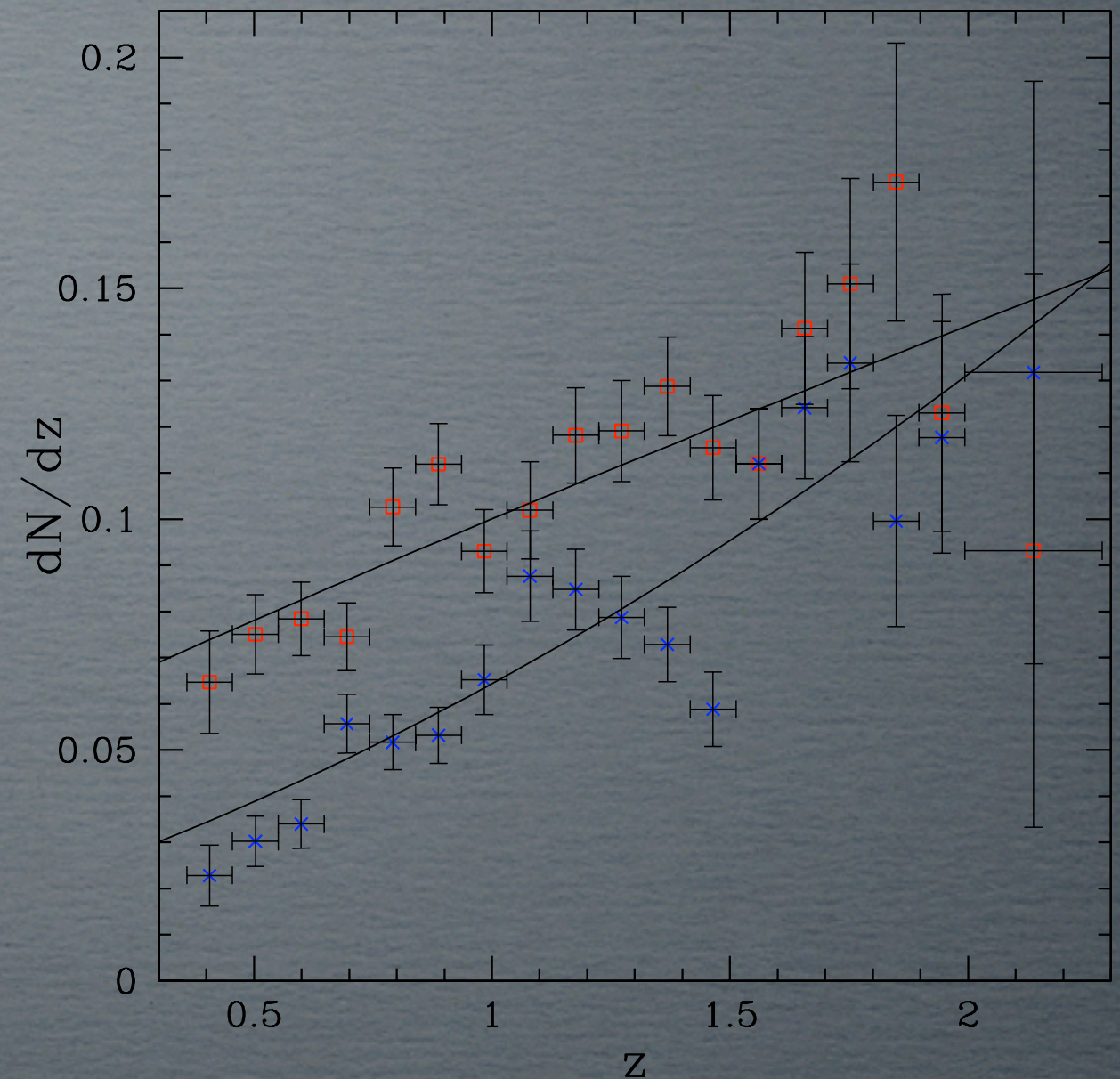
OTHER METAL-LINE SYSTEMS

- **LLS**

- ◆ SEARCH IS UNDERWAY
- ◆ $z > 3.2$
- ◆ CONTRIBUTES CII, CIV +

- **MGII (PROCHTER ET AL.)**

- ◆ DOUBLET SEARCH OUTSIDE THE LYA FOREST
- ◆ ~ 10000 SYSTEMS
- ◆ $\text{SNR} > 7$ SIGHTLINES
- ◆ LARGE NUMBER OF FEII LINES



OTHER FUN QAL SYSTEMS

- QUASAR PAIR (JOE)
 - ✦ SEPARATION IS ~ 40 KPC
 - ✦ Δz IS ~ 0.2
- OBSERVE LLS AT THE FOREGROUND REDSHIFT
 - ✦ $\Delta v \sim 1000$ KM/S
 - ✦ 1/10 SOLAR METALLICITY
 - ✦ $\sim 90\%$ IONIZED
- WHAT IS THE COVERING FRACTION?
 - ✦ WHAT FRACTION OF 'INTERVENING' SYSTEMS?

